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(तीसरा पुनरीक्षण)

Indian Standard

DC ELECTRIC WELDING GENERATORS — SPECIFICATION

(Third Revision)

ICS 25.160.30

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Price Group 6

FOREWORD

This Indian Standard (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Electric Welding Equipment Sectional Committee had been approved by the Electrotechnical Division Council.

This standard was first published in 1964. In the first revision, which was published in 1966, the scope had been enlarged to cover automatic and semi-automatic applications; test for performance characteristics on the basis of best load factor had been discontinued; and the duty cycle had been revised in order to line up with the developments which have taken place at the International level.

The second revision was taken up to modify the temperature-rise values, controls, protective device, etc, and to line it up with IS 6008 : 1971 'Specification for single operator ac/dc arc welding power source'.

The third revision has been undertaken to update the standard bringing in level with international trend. The permissible value of current and speed have been revised.

Arc welding generators are normally driven by either electric motors or diesel or petrol engines. Though the standard has been prepared to cover the technical requirements of generator only, this may also be applied to all generator sets (consisting of generator and prime-movers) for which the requirements are laid down in Annex A.

In the preparation of this standard, assistance has been derived from the following standards:

> ISO 700-1982 Power sources for manual metal arc welding with covered electrodes and for the TIG process. International Organization for Standardization.
>
> BS 638 : Part 10 : 1990 Arc welding power source equipment and accessories: Part 10 — Specification for safety requirements for arc welding equipment: welding power sources. British Standards Institution.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DC ELECTRIC WELDING GENERATORS — SPECIFICATION

(Third Revision)

1 SCOPE

1.1 This standard lays down the requirements, tests and service conditions for dc arc welding (rotary) generators with drooping characteristics for manual, semi-automatic and automatic single metal-arc welding, and with windings with Class A, E, B, F or H insulation (*see* IS 1271).

1.2 Single metal arc welding generator with 'constant potential' output, as opposed to 'drooping characteristics', is not covered by this standard.

1.3 Generators covered by this standard are assigned ratings on the basis of duty cycle.

2 REFERENCES

The Indian Standards listed below are necessary adjuncts to this standard:

IS No.	*Title*
325 : 1996	Three-phase induction motors (*fifth revision*)
1271 : 1985	Thermal evaluation and classification of electrical insulation (*first revision*)
4691 : 1985	Degrees of protection provided by enclosures for rotating electrical machinery (*first revision*)
4722 : 1992	Rotating electrical machines (*first revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Rated Speed

Speed of the generator at rated current

3.2 Rated Current

a) The maximum continuous hand-welding current for manual single metal-arc welding generator to be marked as 'maximum continuous hand-welding current' on the rating plate.

b) The maximum continuous semi-automatic welding current for semi-automatic single metal-arc welding generator to be marked as 'maximum continuous semi-automatic welding current on the rating plate.

c) The maximum continuous automatic welding current for automatic single metal-arc welding generator to be marked as 'maximum continuous automatic welding current' on the rating plate.

3.3 DC Electric Welding Generator

A direct current generator with associated reactors, regulators, control and indicating devices required to produce direct current suitable for arc welding.

NOTE — In this standard the term'generator' is used to indicate dc electric welding generator.

3.4 Manual Metal-Arc Welding (Hand Welding)

Metal-arc welding with consumable electrodes not exceeding 460 mm in length and applied by the operator without automatic or semi-automatic means of replacement.

3.5 Semi-Automatic Arc-Welding

Metal-arc welding in which the arc length is automatically controlled but the positioning of the arc is manual.

3.6 Automatic Arc Welding

Metal-arc welding in which the arc length and the travel of the electrodes or the work pieces are automatically controlled.

3.7 Duty Cycle

The ratio of time during which the generator is loaded to the total elapsed time during one welding cycle (*see* 4.3).

3.8 Maximum Continuous Hand Welding Current

The maximum welding current which the generator is capable of delivering when engaged continuously for manual metal-arc welding, at the specified voltage and the duty cycle without exceeding the stated temperature-rise.

3.9 Maximum Hand Welding Current

The maximum welding current for which the generator is calibrated for manual metal-arc welding at the duty cycle specified by the manufacturer.

3.10 Minimum Hand Welding Current

The minimum welding current for which the generator is calibrated for automatic or semi-automatic metal-arc welding

3.11 Minimum Automatic Welding Current

The minimum welding current for which the generator is calibrated for automatic or semi-automatic metal-arc welding.

3.12 Maximum Continuous Automatic Welding Current

The Maximum welding current which may be supplied by the generator for continuous operation on automatic or semi-automatic arc welding at specified voltage and duty cycle without exceeding the permissible temperature rise.

3.13 Open-Circuit Voltage (OCV)

The voltage between the output terminal (that is, those to which the electrode and return leads are connected) of welding generator ready to weld but carrying no welding current.

3.14 Welding Load Voltage

The voltage between the output terminals of a generator when a specified current is flowing through a resistance load.

3.15 Rating

A statement of operating characteristics assigned to the generator by the manufacturer when tested under specified conditions.

3.16 Type Tests

Tests carried out to prove conformity with the specification. This is intended to prove the general qualities and design of a generator.

3.17 Routine Tests

Tests carried out on each generator to check requirements which are likely to vary during production.

4 RATING

4.1 Rated Open-Circuit Voltage

The open-circuit voltage of generator shall not exceed 100 V. This requirement does not apply to super-imposed high frequency supply.

NOTE — Where it is required to control the open-circuit voltage for safety purposes, suitable safety devices may be incorporated to bring down voltage to the desired value.

4.2 Rated Current

The generators shall be rated for currents at duty cycle corresponding to maximum continuous hand-welding current. Preferred current ratings shall be :

150, 200, 250, 300, 400, 500, 600, and 900 A.

4.2.1 *Minimum Hand Welding Current*

The minimum hand welding current shall be not more than 20 percent of rated current.

NOTE — It is intended that name-plate of the welding generator shall indicate the current not less than 20 percent of the rated current but while checking the conformity of this clause, the tolerance of current calibration in **12.2** should be taken into account.

4.2.2 *Maximum Hand Welding Current*

The maximum hand welding current shall not exceed 1.35 times the rated current.

4.3 Duty Cycle

4.3.1 The rated duty cycle at maximum continuous hand welding current shall be taken as 60 percent; the total duration of each cycle shall be 5 minutes comprising a period of 3 minutes of welding load followed by a period of 2 minutes of no-load operation.

4.3.2 The rated duty cycle at maximum continuous automatic welding current shall be taken as 100 percent.

4.3.3 The rated duty cycle at maximum continuous semi-automatic welding current shall be a matter of agreement between the purchaser and the supplier.

4.4 Tolerances

The permissible tolerances for rated values of current shall be ±10 percent and for the declared values of maximum open-circuit voltage (OCV) shall be ±5 percent, while the declared value of rated speed and speed variation shall be ±10 percent in case of Engines with Mechanical Governors and ±10 percent for Engines with pneumatic Governors.

5 MATERIAL, CONSTRUCTION AND WORKMANSHIP

5.1 Materials

5.1.1 The materials employed in the manufacture shall generally conform to relevant Indian Standards where applicable.

5.1.2 *Insulating Materials*

The insulating materials used in the construction of the generator shall be non-hygroscopic and conform to IS 1271.

5.2 Enclosures

The enclosures shall be of type designation IP 42 of IS 4691.

5.3 Terminals

Terminals of the generator shall be adequately protected against accidental contact. The terminal shall be of adequate capacity and provide good electrical contact.

5.4 Wiring

All joints and connections shall be mechanically secured and shall provide adequate and reliable electrical contact without strains on any connection or terminal.

5.5 Workmanship

All parts shall be manufactured to a high standard of workmanship and finish.

6 SERVICE CONDITIONS

6.1 This standard applies to electric welding generators operating under the following normal service condition:

a) Ambient temperature	Not exceeding 40° C
b) Altitude	Not exceeding 1 000 metres

6.2 Unfavourable Conditions

The use of generator in ambient having temperatures higher than 40°C or at altitudes greater than 1 000 metres requires special consideration. Further unfavourable conditions which are not normal to arc welding process may exist in some cases and it is recommended that they may be brought to the manufacturer's attention. Among such conditions are exposure to :

a) unusual corrosive fumes,
b) steam or excessive humidity,
c) excessive oil vapour,
d) explosive gases,
e) abnormal vibration or shock,
f) excessive dust,
g) weather, and
h) usual sea coast or shipboard conditions.

7 TERMINAL MARKING

7.1 Output Terminals

The polarity of the output terminals shall always be marked in the following manner:

a) Positive terminal	'+'
b) Negative terminals	'–'

7.1.1 In case a polarity change-over switch is provided, the polarities marked are for straight connections only.

8 MARKING

8.1 The following information shall be given on the rating plate :

a) Indication of source of manufacture,
b) Number of Indian Standard (Ref: ISS 2635),
c) Manufacturer's type designation and serial number,
d) Range of welding current (*Min* and *Max*)
e) Maximum continuous hand welding current,
f) Maximum continuous automatic welding current,
g) Maximum open-circuit voltage,
h) Rated speed,
j) Insulation class,
k) Maximum input power required for the prime-mover in kW,
m) Country of manufacture, and
n) A warning worded as follows:

'WARNING — Currents in excess of the following are for intermittent use only.
For hand welding ....Amperes
For automatic welding ....Amperes',

8.1.1 The generator may also be marked with the Standard Mark.

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the rules and regulations made thereunder. The details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

9 EARTHING

Provision shall be made for two separate and distinct connections to earth of all metallic parts which are not intended to carry current. Earthing terminals shall be suitably protected against corrosion and shall be metallically clean. Earthing terminals shall be indelibly marked with the symbol⏚.

10 CONTROL AND PROTECTIVE DEVICES

10.1 The switch, controller or circuit-breaker which may be employed in the arc welding set shall conform to the relevant Indian Standard.

10.2 Contacts of all regulating taps, if provided, shall be such as to make positive contact between moving and stationary contacts.

10.3 Remote control devices, if provided, shall not operate at voltages exceeding 110V.

11 DIRECTION OF ROTATION

11.1 When the generator is suitable for operation at rated load in one particular direction only, this direction of rotation shall be indicated prominently on the body of the generator.

12 PERFORMANCE

12.1 The arc welding generator shall be capable of operating continuously at maximum continuous hand welding current at the specified duty cycle without overheating. The relation between the welding load voltage and the welding current within the range of the welding generator shall be in accordance with Table 1

12.2 Method of Calibration and Accuracy of Graduations

The relation between the welding load voltage and the welding current within the range of the welding power source shall be in accordance with Table 1. The accuracy of the current calibration should be $^{+10}_{-20}$ percent up to the maximum continuous automatic welding current and ±10 percent for current above that.

Table 1 Welding Current and Welding Load Voltage
(*Clause* 12.2)

Welding Current A	Welding Load Voltage V
150	26
200	28
300	32
400	36
500	40
600 and above	44

NOTE — The above load voltages are based on the formula $U = 20 + 0.04\,I$ where U is the load voltage and I is the load current, this formula is applicable to welding currents up to and includung 600 A.

13 COMMUTATION

Generators rated in accordance with this standard shall operate with sparking limits of commutation as specified in No. $1\frac{1}{2}$ of **B-1.2** of IS 4722 for all duties at currents throughout the range of the generator.

14 TESTS

14.1 Tests shall be made to prove compliance with all the requirements of this standard.

14.1.1 *Type Tests*

These tests may be carried out by mutual agreement between the purchaser and the supplier and if the records of type test on a dc electric welding generator which in essential details is representative of the one being purchased are furnished, the purchaser may accept this as evidence of type test instead of actual test. Type tests and their sequence shall be as follows:

a) Insulation resistance test (**14.2**),
b) No-load test (**14.3**),
c) Load test (**14.4**),
d) Temperature-rise test (**14.5**),
e) Commutation test (**14.6**),
f) Short-circuit test (**14.7**),
g) High voltage test (**14.8**), and
h) Insulation resistance test (repeated) (**14.2**).

14.1.2 *Routine Tests*

Routine tests and their sequence shall be as follows:

a) Insulation resistance test (**14.2**),
b) No-load test (**14.3**),
c) Load test (**14.4**),
d) Short-circuit test (**14.7**),
e) High voltage test (**14.8**), and
f) Insulation resistance test (repeated) (**14.2**).

14.1.2.1 A certificate of routine tests shall be furnished by the manufacturer which shall show that each of the welding generator has been subjected to the tests specified in **14.1.2** and that it complies with the requirements specified in this standard for these tests and that each of the welding generator has been found to be sound electrically and mechanically and is in working order in all particulars.

14.2 Insulation Resistance Test

The insulation resistance shall be not less than one megohm. The insulation resistance shall be measured with a dc voltage of about 500 volts applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

14.3 No-Load Test

With the generator running and output terminals open-circuited, the following shall be measured:

a) Open-circuit voltage, and
b) Speed.

14.4 Load Test

The generator output terminals are connected to a variable resistive load. With the generator running at rated speed the welding current at its corresponding setting shall be measured at specified welding load voltage. The currents so measured shall be within the limit specified in **12.2**.

14.5 Temperature-Rise Test

14.5.0 *Test Conditions*

14.5.0.1 The load should be a non-inductive resistance, and at the appropriate load voltage. A tolerance of ±10 percent should be allowed on the value of this load voltage.

14.5.0.2 Welding generators suitable for hand welding shall be tested for temperature-rise (*see* Annex B) at a current equal to the maximum continuous hand welding current and at the duty cycle equal to 60 percent in a duration of 5 minutes. During the test the corresponding load voltage specified in **12.1** shall be maintained.

14.5.0.3 Welding generators suitable for semi-automatic and automatic welding shall be tested for temperature-rise (*see* Annex B) at a current equal to the maximum continuous automatic welding current and at a duty cycle equal to 100 percent. During the test the corresponding load voltage specified in **12.1** shall be maintained.

14.5.1 *Conditions During Temperature-Rise Test*

14.5.1.1 *Ambient temperature*

A generator may be tested at any convenient value of ambient temperature not more than 40°C, but whatever the value of this ambient temperature, the permissible rises of temperature during the test shall not exceed those given in **14.5.2**.

Corrections for variations in the value of the ambient temperature are not considered necessary with in the limits of ambient temperature specified in **6**.

14.5.1.2 *Measurement of ambient temperature during tests*

The ambient air temperature shall be measured by means of several thermometers placed at different points around and half way up the generator at a distance of 1 or 2 metres, and protected from all heat radiation and draughts.

The value to be adopted for the ambient temperature during a test shall be the mean of the readings of the thermometers taken at equal intervals of time during the last quarter of the duration of the test.

In order to avoid errors due to the time lag between the temperature of large generators and the variations in the ambient temperature, all reasonable precautions shall be taken to reduce these variations and the errors arising therefrom.

14.5.1.3 *Correction measurements taken after the generator has come to rest*

a) In case the temperature can be measured only after the generator has come to rest the cooling curve is plotted by determining the first points as rapidly as possible. Two possiblities may arise:

   1) If the part considered cools down evenly from the moment of shutdown, the maximum temperature measurable at the end of the test may be deduced by extrapolation of the cooling curve.

   2) If after shutdown successive measurements reveal temperatures that increase first only to decrease later the extrapolation laid down above becomes inapplicable. It is then accepted that the maximum observable temperature is the highest temperature measured, except if in the vicinity of the measuring points there are other points of the same part for which a higher temperature-rise than at the measuring point is permissible. In this later case, it is sufficient to take the first of the readings which have been taken.

b) The resistance method may be used on generators with one coil side per slot, if the generator comes to a stand still as quickly as possible. In the case of generators with considerable inertia, the extrapolation method should only be used by agreement between the manufacturer and the purchaser.

14.5.2 *Limits of Temperatures and Temperature-Rises*

14.5.2.1 *Temperature-rises*

Table 2 gives the limits of permissible temperature-rise above the ambient temperature for generator insulated with materials in Classes A, E, B, F and H.

For Class C materials, no limits of temperature-rise have yet been assigned.

14.5.2.2 *Temperature corrections for altitudes*

Temperature corrections for altitudes shall be made in accordance with Annex C.

14.5.2.3 *Ambient temperature for temperature-rise test*

Temperature correction for ambient temperature shall be made in accordance with Annex C.

14.5.3 *Duration of Temperature-Rise Test*

The temperature-rise test shall be continued at least until the rate of increase of temperature-rise does not exceed 2°C per hour on any part.

14.6 Commutation Test

A special test to check the quality of commutation shall be made by short-circuiting for 45 seconds the output terminals of the generator with the current setting at its maximum value in the range. During this period, there should not be any injurious sparking nor damage to the commutator.

Table 2 Limits of Temperature-Rise
(*Clause* 14.5.2.1)

Sl No.		Part of Machine	Class of Insulation									
			A		E		B		F		H	
			Thermometer °C	Resistance °C	Thermometer °C	Resistance °C	Thermometer °C	Resistance °C	Thermometer °C	Resistance °C	Thermometer °C	Resistance °C
(1)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	a)	Field windings having dc excitation other than those in Sl No. (ii)	50	60	65	75	70	80	85	100	105	125
	b)	Windings of armatures having commutators										
ii)	a)	Low-resistance field windings of more than one layer and compensating windings	60	60	75	75	80	80	100	100	125	125
	b)	Single-layer windings with exposed bare surfaces or varnished metal	65	65	80	80	90	90	110	110	135	135
iii)		Magnetic core and other parts not in contact with windings	The temperature-rise of these parts shall in no case reach such a value that there is a risk of injury to any insulating or other material on adjacent parts									
iv)		Magnetic core and other parts in contact with windings	60	–	75	–	80	–	100	–	125	–
v)		*Commutators and slip-rings open or enclosed	60	–	70	–	80	–	90†	–	100†	–

*The temperature-rises in Sl No. 5 are permissible provided that insulation appropriate to the temperature-rise is used, except where the commutator or slip-ring is adjacent to windings in which case the temperature-rise should not exceed that for the winding Insulation class. The values of temperature-rise given apply only to the measurements made by bulb type thermometers.

†When permitting temperature-rises of 90°C, and 100°C, special precautions may be necessary in the choice of brush grades and the like.

Under this short-circuit condition the voltage between output terminals shall not exceed 3 V.

14.7 Short-Circuit Test

Steady short-circuit current at any setting within the specified range shall be not more than 200 percent of the welding current corresponding to that setting.

14.7.1 Under short-circuit conditions, the voltage between output terminals of the generator shall not exceed 3 V

14.8 High Voltage Test

14.8.1 A high voltage of 1 000 V plus twice the rated voltage with minimum of 2 000 V shall be applied between the windings and the frame of the generator with the core connected to the frame and in the windings not under test (*see* **14.8.3**). The high voltage test shall be applied once and only once to a new and completed generator in normal working condition, with all its parts in place, and shall be carried out together with the insulation resistance test at the conclusion of the tests laid down in this standard at the manufacturer's works.

NOTES

1 It is generally advisable that the high voltage test should not be applied when the insulation resistance is less than that indicated in **14.2**.

2 Protective or filter devices or capacitors shall be disconnected or short-circuited as desired.

14.8.2 *Supplementary High Voltage Tests*

When for any reason, it is desired to make additional high voltage tests on a generator which has already passed its tests in accordance with **14.8.1**, such additional high voltage test shall be made in accordance with the requirements of **14.8.1**, except that the test voltage shall be 75 percent of the value specified therein. Before applying the supplementary high voltage test, the windings shall be cleaned and the generator shall be thoroughly dried up.

14.8.3 *Method of Making High Voltage Test*

14.8.3.1 The test shall be made with a single-phase alternating voltage as nearly as possible of sine-wave form and of any convenient frequency between 40 and 60 Hz.

14.8.3.2 The rms or peak value of the applied voltage shall be measured. The rms value shall be 2 000 volts.

14.8.3.3 The appropriate voltage, obtained from a separate source, shall be applied for 60 seconds to each windings in turn, between the windings and the remaining windings, core and frame of the generator, connected together and to earth.

14.8.3.4 The test shall be commenced at a voltage of about one-third the test voltage which shall be increased to the full test voltage, in accordance with **14.8.1**, as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage shall then be maintained for one minute. At the end of the minute, the test voltage shall be rapidly diminished to less than one-third its full value before switching off.

ANNEX A

(Foreword)

REQUIREMENTS OF WELDING GENERATOR SET

A-0 GENERAL

A-0.1 The following are the additional requirements regarding the prime-mover, over and above that are given in the standard.

A-1 INTERNAL COMBUSTION ENGINES FOR DRIVING GENERATORS

A-1.1 Internal combustion engines for driving dc generators shall comply with relevant Indian Standards where applicable.

A-1.2 For manual welding, the 1-hour rated kilowatt shall be sufficient to drive the generator at the maximum hand welding current and corresponding load voltage for which the generator is calibrated.

NOTE — The rating of the internal combustion engine corresponds to an ambient temperature of 27°C, atmospheric pressure 100 kPa and 65 percent relative humidity.

A-1.3 For automatic arc welding, the 12-hour rated kilowatt shall exceed the power required for the maximum continuous automatic welding current by at least 10 percent.

A-1.4 Derating for the site conditions shall be agreed to between the purchaser and the manufacturer.

A-1.5 The rated speed of an internal combustion engine shall correspond to the generator speed required to deliver maximum load current and corresponding load voltage as shown in Table 1.

A-1.6 Speed regulation under automatic speed-control of an internal combustion engine measured as the difference between rated speed and no-load speed; under steady load conditions, shall not exceed 10 percent of rated speed.

A-2 GENERATOR DRIVEN BY ELECTRIC MOTOR

A-2.1 Normally induction motor is coupled to the generator. Motor shall conform to IS 325.

A-2.2 Rating of the motor for temperature-rise shall be in accordance with the corresponding requirements of generator at its maximum continuous hand welding current and duty cycle.

A-2.3 The rated speed of the motor shall be the nominal speed at no-load.

A-2.4 Inherent speed regulation of an electric motor measured as the difference between rated speed and speed when driving the generator at maximum hand welding current or maximum continuous automatic welding current and corresponding load voltage, under steady load coniditions, shall not exceed 10 percent of rated speed.

ANNEX B

(*Clauses* 14.5.0.2 *and* 14.5.0.3)

TEMPERATURE MEASUREMENT

B-1 METHODS OF MEASUREMENT OF TEMPERATURE-RISE

B-1.1 Temperature-Rise of a Part of the Generator

The temperature-rise of a part of a generator is the difference in temperature between that part of the generator measured by the appropriate method in accordance with **B-1.3** to **B-1.5** and the ambient measured in accordance with **14.5.1.1** and **14.5.1.2**.

B-1.2 Methods of Measurement of Temperatures

Two methods of determining the temperature of windings and other parts are recognized:

a) Thermometer method, and

b) Resistance method.

B-1.3 For field windings and stator windings of generators or generators having only one coil-side per slot, the preferred method is the increase of resistance of windings.

The thermometer method is applicable in the cases when the resistance method is not applicable.

The employment of the thermometer method is also recognized in the following cases:

a) When it is not practicable to determine the temperature-rise by the resistance method, for example, with low-resistance commutating coils and compensating windings, and in general in the case of low-resistance windings, especially when the resistance joints and connections forms a considerable portion of the total resistance.

b) Single-layer windings revolving or stationary.

c) When for reasons of manufacture in quantity, the thermometer method is used alone, although the resistance method may be possible.

NOTE — It is not intended that measurements by both thermometer method and the resistance method shall be required, and the figures of temperature-rise given in Table 2 for the thermometer method and the resistance method are not to be used as a check against one another.

If the purchaser wishes to have a thermometer reading taken in addition to the values determined by the resistance method, the temperature-rise determined by thermometer, when placed at the hottest accessible spot, shall be the subject of special agreement, but it shall in no case exceed:

65°C if the windings are of Class A insulation

80°C if the windings are of Class E insulation

90°C if the windings are of Class B insulation

110°C if the windings are of Class F insulation

135°C if the windings are of Class H insulation

B-1.4 Thermometer Method

In this method the temperature is determined by thermometers applied to the accessible surface of the completed generator. The term thermometer also includes non-embedded thermocouples and resistance thermometers provided they are applied to the points accessible to the usual bulb thermometers.

B-1.4.1 When bulb thermometers are employed in places where there is strong varying or moving magnetic field, alcohol thermometers should be used in preference to mercury thermometres.

NOTE — The term 'accessible surface' is intended to convey that the established limits of temperature-rise of windings measured by thermometer are based on the use of thermometers placed on the external surface of the windings or iron cores with which the windings may be in contact. The measurements are not intended to cover readings which might be obtained by inserting thermometers into narrow interestices between coils, or between insulating flanges and coils. In such locations the temperature may be higher and allowance is made for this in fixing the permissible temperature-rise measured at the surface.

B-1.4.2 The fact that the type of construction renders a winding difficult of access is not to be taken as permission to operate such windings at higher temperatures than are allowed on those windings or portions of windings on which the thermometers can be more easily placed, and the standard limits of temperature-rise should not be exceeded on any winding surface. If a reasonable proportion of the windings is readily accessible to a thermometer, temperature-rise should be determined by a thermometer placed on these portions of the windings.

B-1.5 Resistance Method

In this method the temperature-rise of the windings is determined by the increase in the resistance of the windings.

B-1.5.1 *Determination of Temperature-Rise of Copper Windings from Increase in the Resistance*

The temperature-rise $t_2 - t_a$ may be obtained from the ratio of the resistance by the formula:

$$\frac{t_2 + 235}{t_1 + 235} = \frac{R_2}{R_1}$$

where

t_2 = temperature (°C) of the winding at the end of the test,
t_a = temperature (°C) of the ambient at the end of the test,
t_1 = temperature (°C) of the winding (cold) at the moment of the initial resistance measurement,
R_2 = resistance (°C) of the winding at the end of the test, and
R_1 = initial resistance of the winding (cold).

For practical purpose, the following alternative formula may be found convenient:

$$t_2 - t_a = \frac{R_2 - R_1}{R_1}\left(235 + t_1\right) + t_1 - t_a$$

When the temperature of a winding is to be determined by resistance, the temperature of the winding before the test, measured by thermometer, shall be practically that of the ambient.

NOTE — For materials other than copper the factor '235' should be replaced in the above formula with the reciprocal of the temperature coefficient of resistance at 0°C for the material.

ANNEX C

(*Clauses* 14.5.2.2 *and* 14.5.2.3)

METHOD OF TEMPERATURE CORRECTION FOR ALTITUDES AND AMBIENT

C-1 TEMPERATURE CORRECTION FOR ALTITUDE AND AMBIENT

C-1.1 Adjustment to Temperature-Rise to Take Care of Operating Conditions of Ambient Temperature and Altitude

This clause applies to generators dependent on cooling by air or other gas at atmospheric pressure where the temperature of the ambient, when specified, is other than 40°C or where the altitude is greater than 1 000 metres.

Where the site altitude is greater than 4 000 metres, the correction for altitude shall be by agreement between the manufacturer and the purchaser.

The site conditions under which the provisions of C-1.1.1 to C-1.1.13 apply are summarized in Table 3.

C-1.1.1 Where a generator is designed to operate with an ambient at a temperature exceeding 40°C but not exceeding 60°C, the permissible temperature-rises shall be reduced below the values given in Table 2 by the ambient by which the specified or stated ambient temperature exceeds 40°C. The permissible correction factor shall be taken to the nearest whole Celsius degree.

C-1.1.2 Where a generator is designed to operate with an ambient at a temperature less than 40°C but not less than 30°C, the permissible temperature-rises may be increased above the values given in Table 2 by the ambient by which the specified or stated ambient temperature is less than 40°C. The permissible rises shall be taken to the nearest whole Celsius degree.

Table 3 Correction of Temperature-Rise Figures with Altitude
(*Clause* C-1.1)

Corrections	Ambient Temperature	Altitude	
		0 to 1 000 m	Above 1 000 m and up to 4 000 m
(1)	(2)	(3)	(4)
Site	Less than 30°C	C-1.1.4	C-1.1.10
	30°C to 40°C	C-1.1.2	C-1-1-11
	40°C	13.5	C-1.1.9
	40°C to 60°C	C-1.1.1	C-1.1.12
	Greater than 60°C	C-1.1.3	C-1.1.8
	Unspecified	—	C-1.1.8
Test	Within 30°C of site temperature	C-1.1.5	*
	Lower than site temperature by more than 30°C	C-1.1.6	*
	Higher than site temperature by more than 30°C	C-1.1.7	*

*Corrections for testing generators for operation above 1 000 metres are under consideration.

C-1.1.3 Where a generator is designed to operate with an ambient at a temperature greater than 60°C, the permissible rises shall be by agreement between the manufacturer and the purchaser.

C-1.1.4 Where a generator is designed to operate with an ambient at a temperature less than 30°C, the permissible temperature-rises shall be increased above the values given in Table 2 by 10°C unless otherwise agreed.

C-1.1.5 When the temperature of the ambient at the inlet to the generator during the temperature-rise test differs from that specified, or assumed from **C-1.1.8** for operation on site by less than 30°C, no adjustment shall be made to the permissible temperature-rise on test.

C-1.1.6 When the temperature of the ambient at the inlet to the generator during the temperature test is lower than that specified or assumed from **C-1.1.8**, for operation on site by more than 30°C, the permissible temperature-rise on test shall be the permissible rise on site reduced by a percentage numerically equal to one-fifth of the difference in Celsius degrees.

C-1.1.7 When the temperature of the ambient at the inlet to the gererator during the temperature-rise test is higher than that specified, or assumed from **C-1.1.8**, for operation on site by more than 30°C, the permissible temperature-rise on test shall be permissible rise on site increased by a percentage numerically equal to one-fifth of the difference, in Celsius degrees.

C-1.1.8 Where the ambient temperature at site is unspecified and the specified altitude is above 1 000 and up to 4 000 metres, the ambient temperature shall be assumed such that the reduced cooling resulting from altitude is compensated for by a reduction in ambient temperature. No adjustment to permissible temperature-rise in Table 2 shall, therefore, be made.

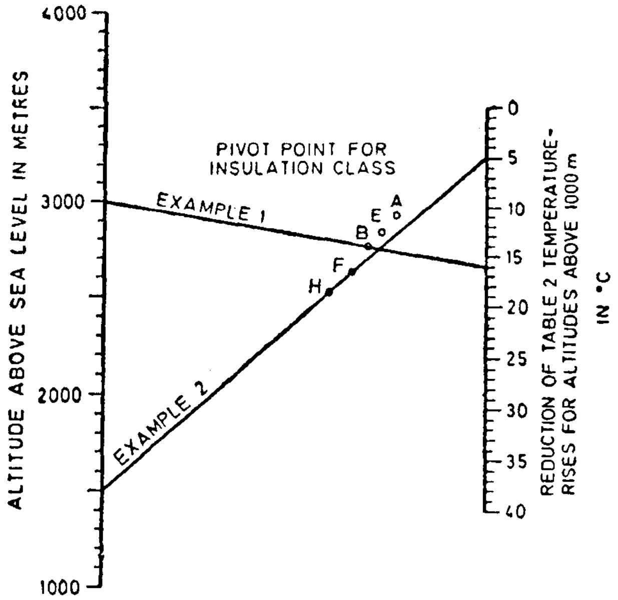
Table 4 shows to the nearest Celsius degree, some assumed ambient temperature (based on a 40°C ambient below 1 000 metres). The decrease of temperature with altitude per 100 metres for each class of insulation is given in Table 5.

Table 4 Assumed Ambient Temperature

(*Clause* C-1.1.8)

Altitude	Ambient Temperature °C for CLass of Insulation				
	A	E	B	F	H
(1)	(2)	(3)	(4)	(5)	(6)
1 000	40	40	40	40	40
2 000	34	33	32	30	28
3 000	28	26	24	20	15
4 000	22	19	16	10	3

C-1.1.9 Where the ambient temperature at site is specified as 40°C and the attitude is above 1 000 and up to and including 4 000 meters the reduction in permissible temperature-rises shall be according to Table 5 per 100 metres of altitude above 1 000 metres. In making the calculations it would be found convenient to use for each class of insulation Increments of altitude which correspond to 1°C, since this will avoid the inconvenience of applying fractional degree corrections to the various values


4000
3000
2000
1000
ALTITUDE ABOVE SEA LEVEL IN METRES
PIVOT POINT FOR INSULATION CLASS
EXAMPLE 1
EXAMPLE 2
A
E
B
F
H
0
5
10
15
20
25
30
35
40
REDUCTION OF TABLE 2 TEMPERATURE-RISES FOR ALTITUDES ABOVE 1000 m IN °C

Example 1:

Altitude 3 000 m. Class B

Correction 16 deg C

Example 2 :

Altitude 1 500 m. Class F

Correction 5 deg C

NOTES

1 Nomogram indicates corrections to be made to temperature-rise in Table 2 due to site altitude above sea level in accordance with **C-1.1.9** to be the nearest whole degree upwards.

2 No correction is made between 0 and 1 000 metres.

FIG. 1 NOMOGRAM

of Table 2. These increments are shown in Table 5. Parts of increments should be graded as whole increments.

Table 5 Temperature Corrections for Different Altitude

(*Clauses* C-1.1.8 *and* C-1.1.9)

Class of Insulation	Decrease in Temperature-Rise in °C per 100 metres	Altitude Increment in metres per °C
(1)	(2)	(3)
A	0.6	167
E	0.7	143
B	0.8	125
F	1.0	100
H	1.25	80

Alternatively the nomogram given in Fig. 1 may be used this purpose, but in cases of dispute the corrections shall be calculated.

C-1.1.10 When a generator is designed to operate with an ambient at a temperature less than 30°C and at an altitude above 1 000 and up to 4 000 metres, the corrections specified in **C-1.1.4** and **C-1.1.9** shall both be applied.

C-1.1.11 When a generator is designed to operate with an ambient at a temperature between 30°C and 40°C and at altitude above 1 000 and up to 4 000 metres, the corrections specified in **C-1.1.2** and **C.1.1.9** shall both be applied.

C-1.1.12 When a generator is designed to operate with an ambient temperature between 40°C and 60°C and at an altitude above 1 000 and up to 4 000 metres, the corrections specified in **C-1.1.1** and **C-1.1.9** shall both be applied

C-1.1.13 When a generator is designed to operate with an ambient temperature greater than 60°C and at an altitude above 1 000 and up to 4 000 metres, the permissible temperature-rise will be by agreement between the manufacturer and the purchaser.

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